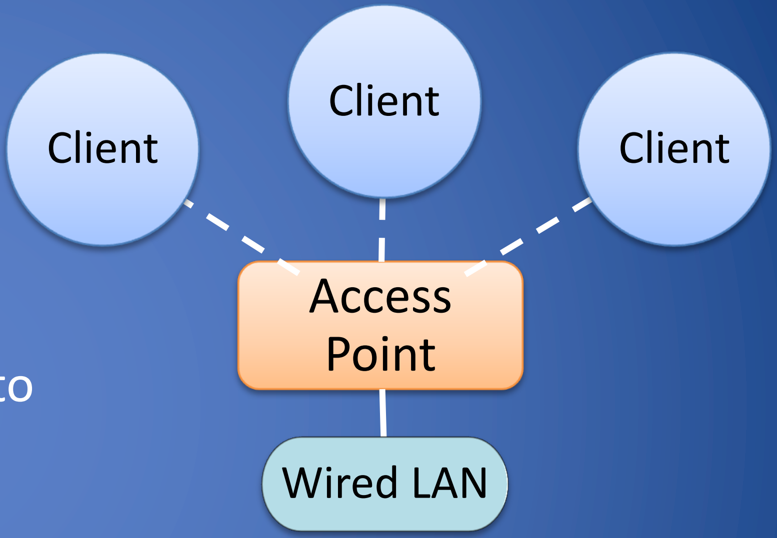
Wireless Networks

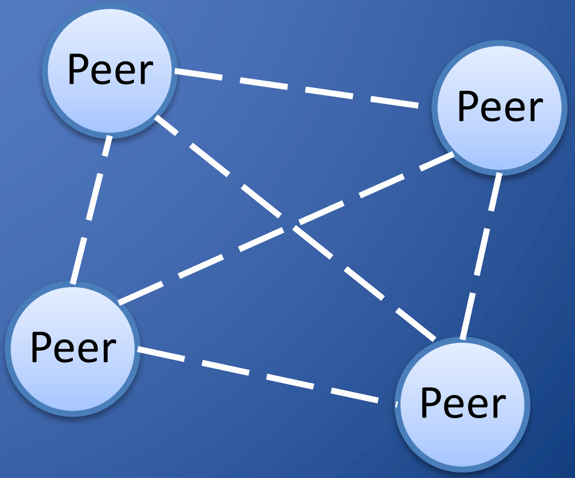
Welcome to Wireless

- Radio waves
  - No need to be physically plugged into the network
  - Remote access
- Coverage
  - Personal Area Network (PAN)
  - Local Area Network (LAN)
  - Metropolitan Area Network (MAN)
- Security concerns
  - Radio signals leaking outside buildings
  - Detection of unauthorized devices
  - Intercepting wireless communications
  - Man-in-the-middle attacks
  - Verification of users
  - Restricting access

Types of Wireless Networks

- Infrastructure
  - Client machines establish a radio connection to a special network device, called access point
  - Access points connected to a wired network, which provides a gateway to the internet
  - Most common type of wireless network
- Peer-to-peer
  - Multiple peer machines connect to each other
  - Typically used in ad-hoc networks and internet connection sharing





SSID

- Multiple wireless networks can coexist
  - Each network is identified by a 32-character service set ID (SSID)
  - Typical default SSID of access point is manufacturer's name
  - SSIDs often broadcasted to enable discovery of the network by prospective clients
- SSIDs are not signed, thus enabling a simple spoofing attack
  - Place a rogue access point in a public location (e.g., cafe, airport)
  - Use the SSID of an ISP
  - Set up a login page similar to the one of the ISP
  - Wait for clients to connect to rogue access point and authenticate
  - Possibly forward session to ISP network
  - Facilitated by automatic connection defaults

Eavesdropping and Spoofing

- All wireless network traffic can be eavesdropped
- MAC-based authentication typically used to identify approved machines in corporate network
- MAC spoofing attacks possible, as in wired networks
- Sessions kept active after brief disconnects
- If ISP client does not explicitly end a session, MAC spoofing allows to take over that session

Captive Portal

- Protocol
  - DHCP provides IP address
  - Name server maps everything to authentication server
  - Firewall blocks all other traffic
  - Any URL is redirected to authentication page
  - After authentication, regular network services reinstated
  - Client identified by MAC address
  - Used by wireless ISPs
- Security issues
  - A MAC spoofing and session stealing attack may be performed if client does not actively disconnect
  - A tunneling attack can bypass captive portal if DNS traffic beyond firewall is not blocked before authentication

Wardriving and Warchalking

- Driving around looking for wireless local area networks
- Some use GPS devices to log locations, post online
- Software such as NetStumbler for Windows, KisMac for Macs and Kismet for Linux are easily available online
- Use antennas to increase range
- Legality is unclear when no information is transmitted, and no network services are used
- Warchalking involves leaving chalk marks (derived from hobo symbols) on the side walk marking wireless networks and associated information

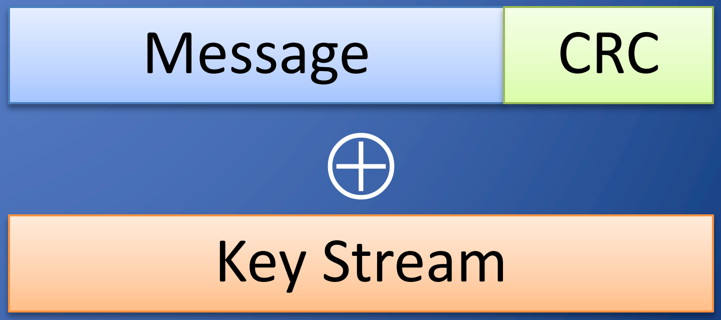
Wired Equivalent Privacy

- Goals
  - Confidentiality: eavesdropping is prevented
  - Data integrity: packets cannot be tampered with
  - Access control: only properly encrypted packets are routed
- Design constraints
  - Inexpensive hardware implementation with 90's technology
  - Compliance with early U.S. export control regulations on encryption devices (40-bit keys)
- Implementation and limitations
  - Encrypts the body of each frame at the data-link level
  - Legacy IEEE 802.11 standard to be avoided

WEP Protocol

- Setup
  - Access point and client share 40-bit key K
  - The key never changes during a WEP session
- Encryption
  - Compute CRC-32 checksum of message M (payload of frame)
  - Pick 24-bit initialization vector V
  - Using the RC4 stream cipher, generate key stream S(K,V)
  - Create ciphertext

    $C = (M \mid\mid crc(M)) \oplus S(K,V)$
- Client authentication
  - Access point sends unencrypted random challenge to client
  - Client responds with encrypted challenge
- Transmission
  - Send $V \,||\, C$



Message Modification Attack

- Message modification
  - Given an arbitrary string Δ, we want to replace message M with $M' = M \oplus \Delta$
  - Man-in-the middle replaces ciphertext C with $C' = C \oplus (\Delta \,||\, crc(\Delta))$
- Targeted text replacement
  - Possible if we know position of text in message
  - E.g., change date in email
- Reason of vulnerability
  - CRC checksum distributes over XOR
  - Not a cryptographic hash function

IP Redirection Attack

- Attacker convinces access point to decrypt packet
- Method
  - Eavesdrop inbound IP packet
  - Resend packet to external machine controlled by attacker
  - Receive packet decrypted by access point
  - Repeat with outbound packets
- Guess destination address
  - Within LAN subnet
- Change destination address
  - Modify original destination D to external machine D′ controlled by attacker
  - Use above message modification method
- Change packet checksum
  - Difference between new checksum and old known $x' - x = (D'_H + D'_L) - (D_H + D_L)$
  - Guess $x' \oplus x$
- Success after few attempts

Reused Initialization Vectors

- Repeated IV implies reused key stream
  - Attacker obtains XOR of two messages
  - Attacker can recover both message and key stream
  - Recovered key stream can be used by attacker to inject traffic
- Default IV
  - Several flawed implementations of IV generation
  - E.g., start at zero when device turned on and then repeatedly increment by one
- Random IV
  - Small length (24 bits) leads to repetition in a short amount of time even randomly generated
  - E.g., collision expected with high probability after $2^{12} \approx 4{,}000$ transmissions

Authentication Spoofing

- Attacker wants to spoof a legitimate client
  - Does not know the secret key K
  - Can eavesdrop authentication messages
- Attack
  - Obtain challenge R and encrypted challenge $C = (R \mid\mid crc(R)) \oplus S(K,V)$
  - Compute key stream $S(K,V) = (R \mid\mid crc(R)) \oplus C$
  - Reuse key stream S(K,V) when challenged from access point

DEMO: WARDRIVING AND WEP CRACKING

Wardriving Tools

- Netstumbler
  wifi scanner

- Antenna for db gain

- Wireless card with
  plug and monitor mode

- GPS (optional)

Wardriving Setup

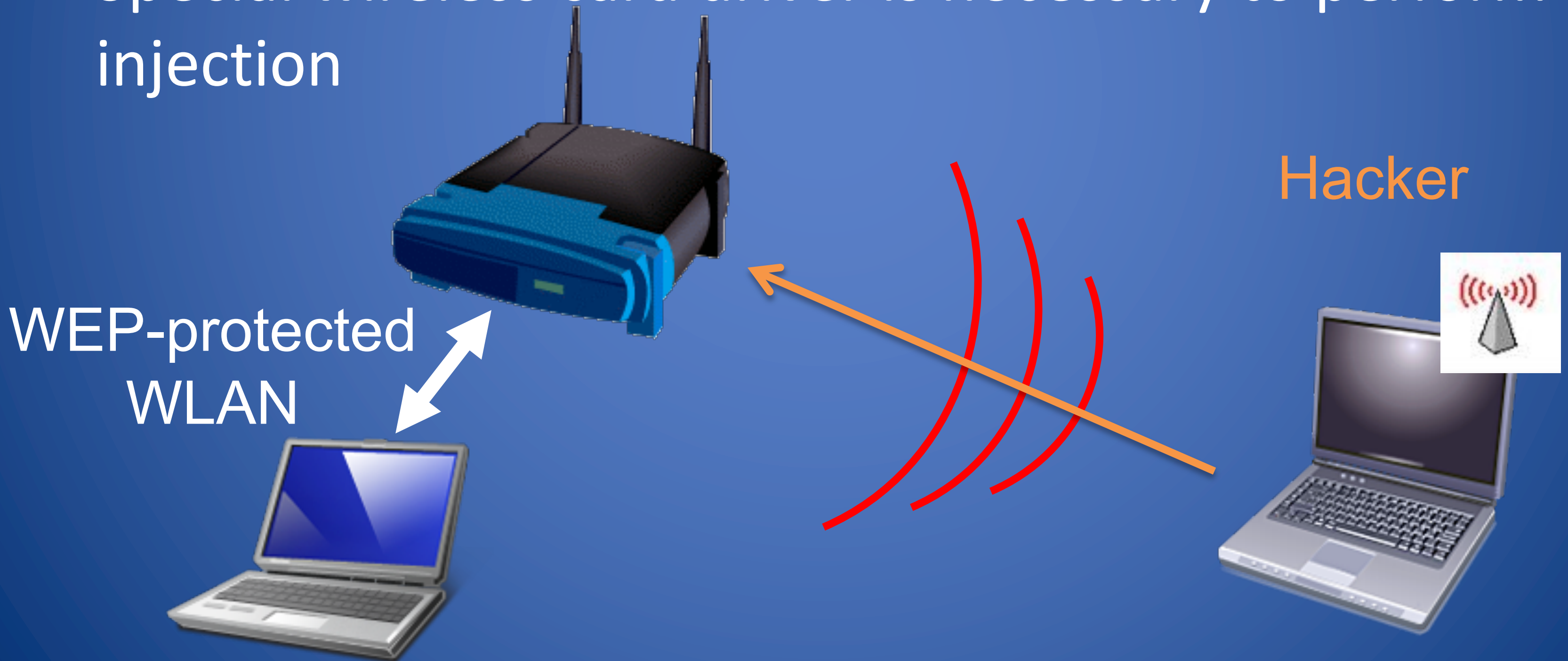
- The access point and client are using WEP encryption
- The hacker is sniffing using wardriving tools

Slow Attack: WEP Sniffing

- To crack a 64-bit WEP key you can capture:
  - 50,000 to 200,000 packets containing Initialization Vectors (IVs)
  - Only about ¼ of the packets contain IVs
  - So you need 200,000 to 800,000 packets
- It can take a long time (typically several hours or even days) to capture that many packets

Fast Attack: Packet Injection

- The hacker injects packets to create a more "interesting" packet
- Special wireless card driver is necessary to perform injection



Initialization vector (IV)

- One for each packet, a 24-bit value
- Sent in the cleartext part of the message!
- Small space of initialization vectors guarantees reuse of the same key stream
- IV Collision:
  - Attack the XOR of the two plaintext messages
  - IV is often very predictable and introduces a lot of redundancy

Injection Method

- Suppose attacker knows one plaintext for one encrypted message, X
  - $RC4(X) \oplus X \oplus Y = RC4(Y)$
  - constructing a new message calculating the CRC32
- Even without a complete knowledge of the packet, it is possible to flip selected bits in a message and successfully adjust the encrypted CRC
- We know ARP, reinject it:
  - ARP will normally rebroadcast and generate IVs

Reference

- Nikita Borisov, Ian Goldberg, David Wagner, Intercepting Mobile Communications: The Insecurity of 802.11. MOBICOM, 2001.

Wi-Fi Protected Access (WPA)

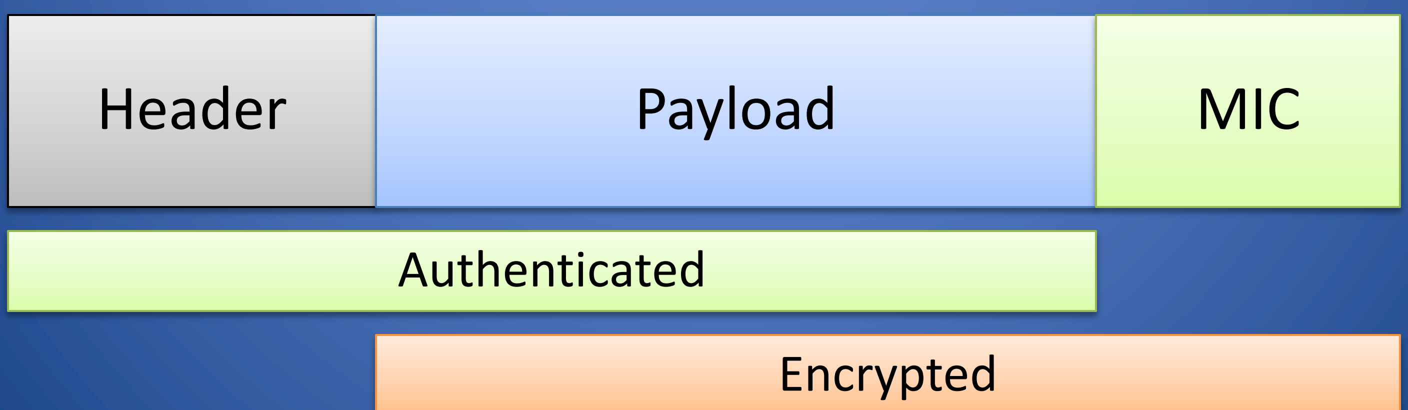
- WEP became widely known as insecure
  - In 2005, FBI publically cracked a WEP key in only 3 minutes!
- Wi-Fi Protected Access (WPA) proposed in 2003
- Improves on WEP in several ways:
  - Larger secret key (128 bits) and initialization data (48 bits)
  - Supports various types of authentication besides a shared secret, such as username/password
  - Dynamically changes keys as session continues
  - Cryptographic method to check integrity
  - Frame counter to prevent replay attacks

WPA2

- WPA was an intermediate stepping-stone
  - Final version: IEEE 802.11i, aka WPA2
- Improvements over WPA are incremental rather than changes in philosophy:
  - Uses AES instead of RC4
  - Handles encryption, key management, and integrity
  - MAC provided by Counter Mode with Cipher Block Chaining (CCMP) used in conjunction with AES
- WPA2 needs recent hardware to operate properly, but this will get better over time

WPA2 Encryption

- Counter Mode with Cipher Block Chaining Message Authentication Code Protocol
- Compute a 64-bit message integrity code (MIC) on the plaintext header and the payload using the Michael algorithm
- Encrypt the payload and MIC
- Michael is not a strong cryptographic hash function



Alternatives and Add-Ons

- WEP, WPA, and WPA2 all protect your traffic only up to the access point
  - No security provided beyond access point
- Other methods can encrypt end-to-end:
  - SSL, SSH, VPN, PGP, and so on
- End-to-end encryption is often simpler than setting up network-level encryption
- Most of these solutions require per-application configuration